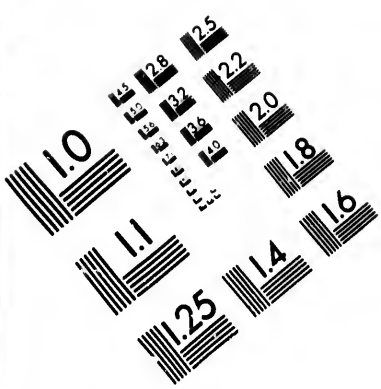

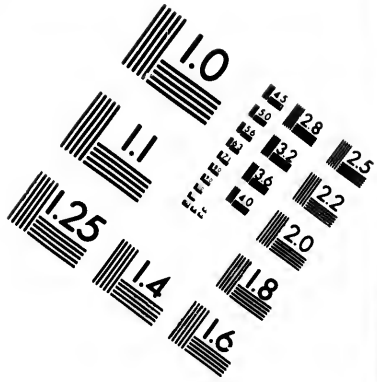

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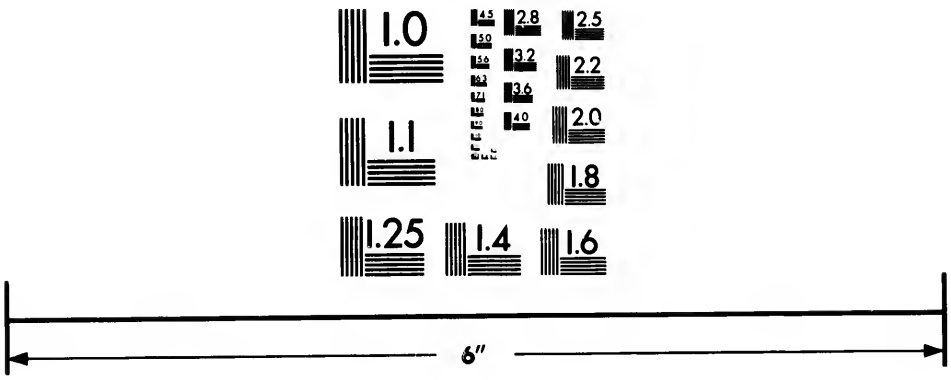

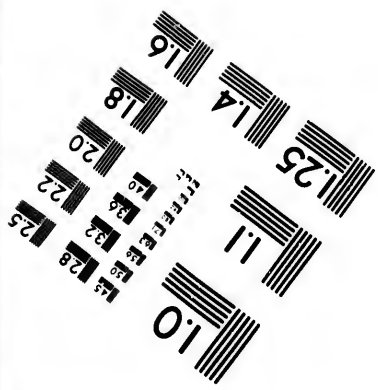

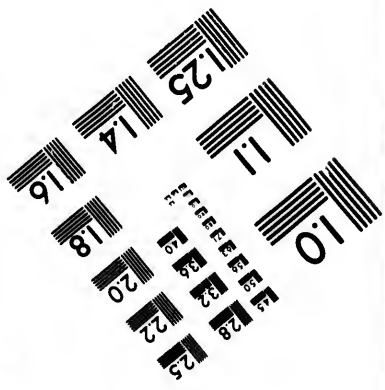

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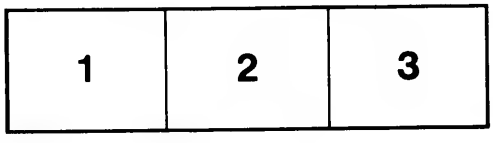

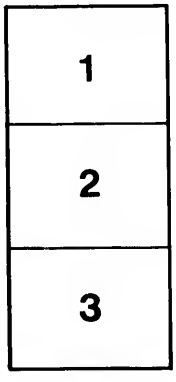

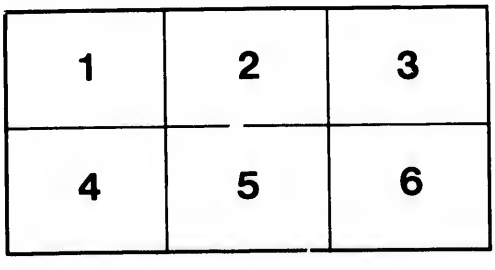

DISCOVERY OF STONE IMPLEMENTS

IN

GLACIAL DRIFT

IN

NORTH AMERICA

BY

THOMAS BELT, F.G.S.

Reprinted from the QUARTERLY JOURNAL OF SCIENCE, *January*, 1878.

LONDON.

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ON THE DISCOVERY OF STONE IMPLEMENTS IN GLACIAL DRIFT IN NORTH AMERICA.

THE discovery of great numbers of stone implements in New Jersey, by Dr. C. C. Abbott, in deposits which are probably of Glacial age, is of such great importance that a detailed account of the beds in which they have been found and a discussion of their antiquity will be interesting to many. I had, during the past autumn, an opportunity of studying these beds under the kind guidance of the discoverer of the implements; and I am also indebted to Prof. Cook and Prof. Smock, of the Geological Survey of New Jersey, for much information respecting the glaciation of the State. I shall, in the first place, give a brief statement of what was before known of the earliest traces of man in North America.

Before these discoveries there had been many intimations of the great antiquity of man in the western hemisphere. Probably one of the earliest of these was the discovery of the fragment of a human bone which was said to have been found at the base of 60 feet of loess, near Natchez, on the Mississippi, along with the remains of the megalonyx and other extinct quadrupeds. A full description of the deposits in which these remains were discovered has been given by Sir Charles Lyell, in his "Second Visit to the States."* We learn there that Dr. Dickeson, of Natchez, felt persuaded that the fragment of human bone had been taken out of the clay underlying the loam; but Sir Charles Lyell could not ascertain that it had been actually dug out in the presence of a geologist, or any practised observer, and he speculated on the possibility of it having fallen from above, into the bed of the ravine, from some old Indian grave. This was in 1846: long afterwards, when the discoveries in Europe had established the contemporaneity of man and the great extinct pachyderms, he recalled the fact

* *Op. cit.*, vol. ii., p. 196.

that the human bone was in the same state of preservation and of the same black colour as the bones of the mastodon and megalonyx, said to have been found with it; and he was disposed to think that he had discussed its probable age with a stronger bias, as to the antecedent improbability of the contemporaneous entombment of man and the mastodon, than any geologist would now be justified in entertaining. *

The fragment of a human skull from Calaveras, in California, which was said to have been found in gravel beneath five successive overflows of lava, would, if authenticated, be probably the oldest record of man in North America. The same doubts, however, have been expressed about it as about the Natchez remains, no geologist being present when it was exhumed. In the newer gold-drifts of California, along with the remains of the mastodon, elephant, tapir, bison, and horse, the implements of man have been frequently found.†

In the auriferous gravels of Kansas and Georgia stone and flint implements have also been discovered.‡

Dr. Samuel Aughey, in his account of the superficial deposits of Nebraska, states that the remains of elephants and mastodons are often found in the loess that overspreads nearly the whole of the State. In this deposit, in a railway-cutting near Omaha, 20 feet from the surface, he dug out himself a large coarse arrow- or spear-head which lay 13 inches below the lumbar vertebra of *Elephas americanus*.‖

Near Alton, in Illinois, stone axes and flint spear-heads along with the bones of the mastodon are reported from drift below loess.§

All the above discoveries are in regions that drain either into the Pacific or the Gulf of Mexico.

Mr. Chas. M. Wallace has described the discovery by him of flint implements in stratified drift near Richmond, Virginia.¶ These deposits seem to be similar to those in which Dr. Abbott has made his discoveries in New Jersey. The valley of the James River is mantled by thick deposits of coarse gravel covered with brick-clays. The implements have been found occasionally in the clay, and more frequently

* Antiquity of Man, first edition, p. 200.
† J. D. Whitney, Geol. Surv. California, vol. i., p. 252.
‡ Dr. D. Wilson, Canadian Journal of Science, October, 1877, pp. 559, 560.
‖ Geol Surv. of the Territories, 1876, p. 254.
§ Geol. Surv. Illinois, 1866, vol. i., p. 38.
¶ Amer. Journ. Science, March, 1876, vol. xi., p. 195.

in the underlying gravel. One of the sections given by Mr. Wallace shows the following succession of beds:—

	Feet.
Brick earth underlying greyish clay ...	9
Rounded gravel, reddish hue	4
Fine bluish sand...	12
Gravel and bluish pebbles...	4
Compacted sand (probably Tertiary).	

Several implements were found on the surface of the lower bed of gravel. This lower gravel contains large numbers of the pebbles from which the implements, for the most part, appear to have been fashioned. In some parts large boulders (one 8 ft. by 12 ft.) rest upon the gravel, and appear as if they had been brought by floating ice and deposited in gentle waters. Mr. Wallace notes the similarity of many of the implements to those of palæolithic age in Europe. I believe this is the first notice of the discovery of palæolithic implements on the eastern sea-board of North America,

The report by Dr. C. C. Abbott of his discoveries of stone implements in the drift-gravels near Trenton, New Jersey, appeared in the "Tenth Annual Report of the Peabody Museum," issued during the present year.* My attention was drawn to it, soon after its publication, by Dr. D. Wilson, of Toronto,—who has since reviewed Dr. Abbott's paper,†—and in consequence I visited the locality. Dr. Abbott showed to me a great number of the implements he had found, and afterwards accompanied me to the principal places near Trenton from which they had been obtained.

Whilst a few of the implements resemble some of the palæolithic chipped flints of England and France, the general form and type is of a ruder and more imperfect character. Some are simply made from rounded flat pebbles by chipping a cutting edge at one end. Amongst them are many of what Dr. Abbott has named the "turtle-back" type. It appears to have been formed by using a pebble with one side naturally flat, or by producing a flat surface by artificial fracture and bevelling down the other side by chipping, so as to produce a cutting edge.

Whilst the general character of the implements is ruder than the European, a few appear more like a spear-head than I have seen amongst the latter. I have shown a few,

* *Op. cit.*, p. 30.
† Canadian Journal of Science, October, 1877, p. 557.

that Dr. Abbott liberally presented to me, to our greatest authority on stone implements, Dr. John Evans, and he considers they are different from the palæolithic type in Europe, and more resemble some of the ruder neolithic implements from Ireland. It is surprising that palæolithic implements from distant parts of the Old World resemble each other so closely, and it would have been more wonderful if those from America had been fashioned to the same type.

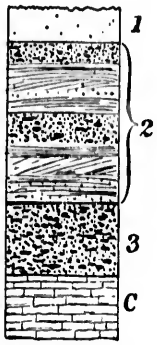
Most of these implements are from the high bluff facing the Delaware, near Trenton; some from other localities in the same valley. Amongst them is one which Dr. Abbott picked out himself from the face of a railway-cutting through a boulder deposit at Butzville, 50 miles north of Trenton. It is made from a flattened pebble, by one end being chipped to a cutting edge, the other being left in its natural rounded condition. Both on the rounded portion of this specimen and on the chipped part are what appear to be glacial scratches. Dr. Abbott informed me that nearly every stone in this deposit was covered with glacial striæ, and Professor Smock afterwards told me that the formation had been recognised by the Geological Survey as part of the terminal moraine of the great ice-sheet. I felt no doubt when I examined this specimen that it had been fashioned by man, but Dr. Abbott has since informed me that others to whom he has shown it think that it is barely possible that it may be of natural formation. I fully expect that it will be authenticated by further discoveries, but in the meantime it may be well not to base any theories upon it. I noticed small scratches upon some of Dr. Abbott's other specimens, and he kindly presented one to me showing these on one side. As I shall have to explain further on, the glacial age of at least some of these implements can be proved without reference to the one from Butzville, or whether the scratches on others are glacial or not; and I am disposed to place less value on the striæ on the Trenton specimens, because it is obviously possible that they may be artificial.

Opposite Dr. Abbott's house, about 2 miles below Trenton, the high bank bounding the river has been worn back into a deep bend, and a wide alluvial plain now lies between it and the Delaware. I sketched the section of the beds forming the bluff (Fig. 1) at this point. The top bed is here an unstratified sandy clay, with a few scattered pebbles, and occasionally very large boulders, none of which were, however, seen at this locality; beneath this lie alternations of fine sandy gravel, sand, coarse gravel, and boulder-beds. Dr. Abbott pointed out to me the upper layer of pebbles as

the horizon from which he had obtained some of the implements in undisturbed ground.

Towards Trenton the bluff approaches the river, and just below the town forms its bank. The face of the bluff is

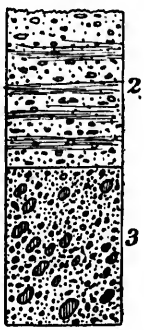
FIG. 1.



1. Sandy clay, 3 to 6 feet, with large boulders on surface in some places.
2. Alternations of gravel and sand, occasionally false bedded, 6 to 10 feet. Stone implements.
3. Unstratified pebble and boulder bed. Thickness very variable.
C. Cretaceous marls and clays.

mostly a talus; there are few good sections, and none that I saw were perfectly satisfactory. The best section was near the cemetery, where I made the sketch shown in

FIG. 2.



2. Irregularly stratified sand and gravel, with occasionally larger stones intermixed, about 12 feet. Stone implements.
3. Thick unstratified bed of pebbles and boulders, mostly rounded, with many stones up to 15 inches diameter; larger ones rare. Base of deposit not seen.

Fig. 2. The lower bed (No. 3) is quite unstratified; only the upper 12 feet of it is seen where the section was taken, the lower part being covered with talus, but in other places

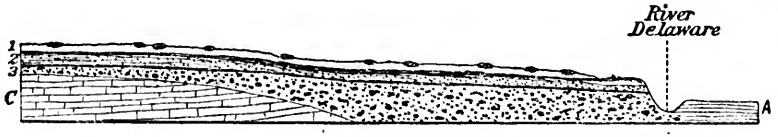
it was seen going down to and below the river, the surface of which is about 40 feet below the top of the bluff.

The irregularly stratified beds, No. 2, contain generally much smaller stones than No. 3. These beds, as in the former case, were pointed out to me by Dr. Abbott as the ones from which he had obtained the implements, and whilst I was present he discovered a rude one in the talus which appeared to have come from them, as we were too high up the slope for it to have come from the lower bed.

The bed of sandy clay (No. 1 in Fig. 1) has been denuded from the top of the bluff, but a little way back from the edge it appears, and contains great boulders scattered over its surface.

From all the sections that I saw, and from the information given to me by Dr. Abbott, I have constructed the general section (Fig. 3) showing the succession of the beds. Up to

FIG. 3.—DIAGRAM SECTION BELOW TRENTON.



1. Sandy clay, unstratified, with a few pebbles, and with very large far-transported boulders on or immediately below the surface.
2. Irregularly stratified sands and gravels. Stone implements.
3. Pebble and boulder bed. Stones up to 15 inches across plentiful; larger ones rare. Stones mostly rounded, with a few subangular ones; no scratched ones seen
A. Alluvium.
C. Cretaceous marls and clays.

the time of my visit (October, 1877) no implements had been found in the lower quaternary bed (No. 3), though it seems to me extremely likely that they will yet be discovered. This bed, of mostly rounded boulders and large pebbles, is quite unstratified. Amongst the pebbles are many flattened ones, similar to those from which some, if not all, the implements found in the higher beds have been made. This rounded boulder-bed is of great extent, and has been described by Prof. W. B. Rogers* as extending from the Delaware into Virginia. At Washington the deposit covers the whole plain on which the city is built, rising to a height of about 200 feet above the sea over the low hills around it. Prof. Rogers has found in it stones containing *Scolithus linearis*, a well-known fossil of the Potsdam formation, having its nearest outcrop on the western side of the Blue

* "On the Gravel and Cobble-stone Deposits of Virginia and the Middle States." Proc. Bos. Soc. Nat. Hist., 1875, vol. xviii.,p. 101.

Ridge. Some of the stones found near Richmond must have been brought 80 miles if they travelled in a direct line from the parent rock. At Richmond this deposit is said to present itself at various heights from the river-bank to the tops of the hills, mantling the irregularly denuded surface of the underlying formations, resting at one place on the Upper Miocene, at others on the Eocene, or yet older deposits.*

At Trenton this deposit is principally composed of crystalline rocks, many of distant origin, but none I believe have been noticed that may not have been derived from formations existing within the drainage area of the Delaware and its territories. Trenton is often mentioned as being about the southern limit to which the northern ice reached in the valley of the Delaware in glacial times, but I could find no traces of glaciation in the neighbourhood; and Prof. Cook informed me that it has not been noticed farther south in the valley than near Belvidere, about 50 miles in a direct line N.N.W. from Trenton. Prof. Cook and Prof. Smock have now traced the southern boundary of the land ice pretty clearly across the State of New Jersey, from the neighbourhood of Amboy, on the Atlantic coast, to Belvidere, on the Delaware. From thence it runs across to near Harrisburg, in the valley of the Susquehanna, where Prof. J. P. Lesley informed me were the most southern glaciated rock surfaces in that valley. North of an undulating line passing through these points the surfaces of the bed-rocks are rounded and polished, and scored with glacial striæ. By means of these markings, and by the direction from which transported rocks have been brought from their parent beds, the course of the ice has been mapped out from the Canadian boundary, where it was so thick as to be able to over-ride and move independently of the valleys, up to its southern termination, where it is found conforming with the direction of the main drainage channels. South of the line to which the northern ice extended the rock surfaces are often decomposed to a great depth. This is especially evident where the bed-rock is gneiss or granite. In such cases, for more than 50 feet from the surface, the rocks have often been changed to a clay that may be dug with a spade; whilst that it has not been otherwise reconstructed is evidenced by the fact that veins of quartz running through it remain in their original position.† Over the glaciated

* *Ibid.*, p. 106.

† See T. Sterry Hunt, "Decomposition of Crystalline Rocks." Amer. Journ. Sci., 1874, vol. vii., p. 60.

district, on the contrary, the decomposed crust has been removed, and the hard unaltered rock laid bare.

It has been shown that the decomposition of the rocks has been caused by the slow percolation of rain-water containing a little carbonic acid. It follows that the surface rocks had been exposed for long ages to this influence, and that the time that those of the glaciated districts have been subjected to the same action, since the Glacial period, is exceedingly short in comparison.

Another mark by which the glaciated may be distinguished from the non-glaciated country is by the occurrence of a deposit long known in Scotland under the name of "till," and on the Continent as "grund morane" and "moraine profonde." It is generally a stiff clay, full of small angular fragments of the rocks over which the ice has passed, and sometimes with large angular and subangular stones. It always more or less reflects the characteristics of the strata immediately in the neighbourhood and in the direction from which the ice has come. Thus in the vicinity of Toronto I noticed, as Mr. G. J. Hinde had before remarked,* that the till is packed with small fragments of black Utica shale and blue Trenton limestone –strata that the ice had passed over in its passage from the eastward. Along with these were larger fragments and slabs of the underlying Hudson River group, and a few rounded boulders of gneiss that were far travelled. Around New York many patches of till are left on the glaciated rocks. I visited Marion, near the city of New Jersey, by the advice of Prof. Cook, and found very fine sections of the glacial beds. The till is there not a stiff clay, but a rather sandy deposit, of a dark reddish brown colour, packed with the angular *débris* of the red triassic sandstones that form a large portion of the bed-rocks of eastern New Jersey. A few of the contained stones may have been brought from a distance, but the great bulk of them, as well as the sandy matrix, are of local origin.

The deposition of the till probably took place during the melting back of the ice-sheet. Dr. Dana has shown that the ice was very thick over New England, and that the pressure at its base would be so great as to force the plastic mass into the crevices of the rocks below, so as to tear off fragments from them, which, with any loose material it met with in its progress, would be gathered up and borne along in the lower portion of the ice-sheet.† Prof. Joseph Le Conte,

* Canadian Journal, April, 1877, p. 8.

† "On the Glacial and Champlain Eras in New England." Amer. Journ. Sci., March, 1873.

in his study of the deposits left by the ancient glaciers of the Sierra Nevada,* has arrived at a similar conclusion. Prof. Hall, in his "Geology of New York," has given a large picture of a natural section on the shore of Lake Erie, in Chautauque county, where we may see as it were the till in course of formation. In some parts the top strata are only a little separated, with clay forced in between them; in others they stand on edge, or are broken up and the fragments scattered throughout the till.† I have seen similar instances on the shores of Lake Ontario. In our own country there are also many examples of the same action; one of the finest, that I have seen, being in the beautiful section of the glacial beds exhibited in the cliffs at the mouth of the Tyne, in Northumberland. In this way the lower portion of the ice appears to have become charged with stones and finer materials which were left on the surface when the great glacier melted back. The till is therefore restricted to the area that the land-ice covered, and is as much a memorial of its former presence as the scratched and rounded rocks on which it generally lies.

By the glaciated rock-surfaces up to the line I have already mentioned and their absence beyond, by the outspread of the till limited by the same boundary, and by the disappearance of the decomposed surface-rocks up to but not beyond that margin, we know that the land-ice did not reach, in the valley of the Delaware, farther than the neighbourhood of Belvidere, which is 50 miles to the north of Trenton. What relations, then, do the beds of drift that I have described at Trenton bear to the ice-sheet? To answer this question we must take into consideration what we know is taking place at the terminations of existing glaciers. Great streams of water run from underneath them, bearing along fragments of rocks that have been melted out of the glacier or fallen through crevices to the subglacial rivers. These are rounded by attrition, and spread out in sheets of pebbles often extending for miles below the terminations of the glaciers. From the enormous glacier that once filled the Delaware valley as far as Belvidere, and which was itself only a southern prolongation of the still greater northern ice-sheet, there must have been shed a vast amount of similar material. The large rounded drift that lies at the base of the quaternary beds at Trenton (No. 3 in Figs. 1, 2, 3) is almost undoubtedly a similar

* Amer. Journ. Sci., 1875, p. 126.
† *Op. cit.*, Plate VIII.

deposit. It contains a mixture of all the various rocks over which the glacier of the Delaware would pass; those from the hardest formations being most abundant, as they would best survive the severe abrasions to which they had been subjected.

No implements are yet reported from this bed, so that, putting aside the disputed implement from the morainic accumulation at Butzville, we have no evidence at present that man frequented the valley of the Delaware before or during the greatest extension of the glacier of that valley. The deposits from which Dr. Abbott has obtained the implements lie above this great unstratified bed of rounded drift, and we should have great difficulty in fixing the approximate age of the implement-bearing strata if it were not for the fortunate occurrence of the sandy clay with large boulders (No. 1 in Figs. 1 and 3) clearly superimposed on the latter. We may now turn our attention to the consideration of this surface-bed and the relation it bore to the Glacial period.

In my discussion of the glacial and post-glacial phenomena bearing on the date of the excavation of the gorge at Niagara, published in this Journal,* I have described the occurrence of large boulders of crystalline rocks lying above all the other glacial beds. In the till which lies next the glaciated bed-rocks the stones are all of local origin; in the surface deposit they are all from the distant north.

Prof. James Hall, so long ago as in 1843, had fully recognised the importance of the occurrence of these far-transported blocks that lie scattered over the surface, and had noted the difference in the mode of their occurrence and in their composition from the rocks included in the lower glacial beds.† He shows that the glacial beds belong to two periods: one, the lower, which contains mostly local rocks; the other, the upper, containing far-transported crystalline rocks. He says that on the broad northern slope towards Lake Ontario, where hills are distant, there are numerous and extensive fields of boulders resting upon the surface, or but partially imbedded in the soil, and holding such a position that it is evident that they are of subsequent origin to the great body of detritus; and again, on the western prairies, long lines of boulders are to be observed stretching away for miles beyond the reach of vision, as if once forming a line of coast or deposited along some channel

* *Op. cit.*, April, 1875.
† Geology of New York, Part IV., pp. 319 to 321.

or course of a current, though the general surface indicates no influence upon this portion beyond what is common to the whole. Prof. Hall considered that there was no explanation of the transport of these great blocks, excepting on the supposition that the whole surface was covered with water, over which they were floated on icebergs. "Had they been transported," he says, "by a powerful current over the bottom (which cannot be supposed from the inequalities of the surface) all the older drift would have been removed at the same time, and instead of finding them as we do now, mostly upon the surface, they would have been imbedded indiscriminately in the superficial detritus, and there would have been no means of recognising the products of different periods."*

Dr. Newberry, in his "Surface Geology of Ohio," has fully described the distribution of large boulders over the surface of that State. Even in Southern Ohio they are in some parts very numerous. He says that the large unscratched boulders are generally found on the surface, and that in the great series of excavations, which have been made in the construction of the railways and canals, they have been rarely met with below it. They are often seen resting on the fine stratified clays which form the upper part of the drift. And he observes that "it seems impossible that they should have been brought to such positions by glaciers or currents of water, as either of these agents would have torn up the underlying clays. We also learn, from their relative position, that these boulders were deposited at a later period than the most recent stratified beds of the drift series, and that they were floated to their present resting-places. In short, no argument is required to convince anyone who will glance at the facts that these boulders, and probably the gravel and sand with which they are sometimes accompanied, were floated on icebergs from the north shore of the great fresh-water lake which once filled the lake basin, and that as these icebergs melted, or when they stranded, their loads were discharged on the top of all the drift deposits which had been laid down in the preceding epochs of the Quaternary age."†

On the eastern side of the Appalachians, Prof. Hall has noticed the occurrence of these boulders in the valley of the Hudson, and says that he has searched in vain, near Albany and Troy, for a boulder or pebble of granite, or of

* *Ibid.*, p. 336.
† Surface Geology of Ohio, 1874, p. 40.

any rock older than the Potsdam sandstone in the deposits below the clay; while in a period subsequent to the deposition of the clays and sands, boulders of granite are by no means rare.*

In the southern part of the State of New York and in New Jersey they are not uncommon. At Marion, at the section of the till to which I have already referred, the top bed is a light-coloured sandy clay, similar to that at Trenton. Lying on and sometimes imbedded in this are large boulders, scattered over the surface. The sandy clay rests directly on the till, and is about 3 feet thick. Both here and at Trenton these great boulders were much larger than any I saw in the underlying till or drift. At Trenton they are often seen in the formation of new streets on the outskirts of the town. Some of them are 7 or 8 feet across, and most require blasting before they can be removed. I learnt from Prof. Smock that these blocks are distributed over much of the State, and he spoke of particular boulders occurring at a considerable altitude. I do not know, however, how high they occur, but probably this interesting question will be worked out by the Geological Survey of New Jersey, as well as the distances which they must have travelled from their parent rocks.

Nor does the Delaware form the southern limit of the far-transported boulders. They appear to bear the same relation to the drift-beds in Virginia, for Mr. Wallace, in his account of the discovery of stone-implements near Richmond, speaks of boulders in the surface-soil, and of large blocks (8 feet by 12) resting on the gravel.

It is obvious, as Prof. Hall and Dr. Newberry have pointed out, that these great blocks of stone must have been carried to their present position by floating ice. Any flood of water sufficient to move them would certainly wash away the sandy loam in and on which they rest, and such a mode of transport would not account for their position scattered here and there over the great undulating plain that extends from Trenton to the sea; nor could they have been left by the great ice-sheet, as they are found far beyond the limits to which it reached. Sometimes we hear the distribution of the upper glacial beds ascribed to a second Glacial period, when the ice again covered the land. But ice could not have moved thus for hundreds of miles over beds of gravel and sand without disarranging them, and nowhere in America has any sign been noticed of a second advance of

* Geology of New York, Part IV., p. 319.

the northern ice. We have thus two distinct phases of the glacial era clearly marked in North-eastern America,—a Glacier period and an Iceberg period, just as we have in Europe. They are distinct in their range and distinct in their effects. In the first—the Glacier period—the ice, moving gradually southward, scored and polished the rocks over which it passed, and left behind it the unstratified till containing principally scratched fragments of local rocks. In the other—the Iceberg period—rocks were carried many miles beyond the limit that the glacier ice reached to, and were dropped on the top of loose unconsolidated clays and sands, which show no trace of any abrading or disturbing force. In Europe the ice from the Scandinavian mountains reached to the southern side of the Baltic, and for the whole distance the bed-rocks are glaciated; but beyond this the iceberg drift is scattered for hundreds of miles, and extends to the flanks of the mountain-chains that bound the German plain to the south; and that icebergs do not, as a rule, glaciate the beds over which they pass may be gathered from this,—that as soon as the boundary is left behind to which the land-ice undoubtedly reached no more glaciated rock-surfaces are seen; not even on the hills on which the icebergs must have grounded, as they have left there the greater part of the rocky burden they carried.

The agency of floating ice in the distribution of boulders was early recognised by geologists; but when, later on, Agassiz proved that land-ice had also played a most important part, it was not clearly perceived that both agencies were required to interpret the phenomena, and to this day the till—the product of the land-ice—is often confounded with the boulder clay, the product of the floating ice. In no other department of geology is far-travelled experience more necessary than in the study of the glacial beds. The knowledge to be acquired in a single province, or even in a single country, is not sufficient, for it will be well nigh impossible from that alone to separate what is particular and local from what is widespread and general. To limited experience I cannot help believing is due the obscurity to be observed in many of the memoirs dealing with glacial problems. One authority, who has perhaps lived amongst northern mountains, ascribes everything to the action of glaciers; another, whose home, maybe, has been on southern plains, sees nothing but the agency of water and floating ice.

In studying the glacial beds of North-eastern America we must seek to give their proper importance both to

glaciers and icebergs, and to separate the phenomena into the two classes to which they belong. When we do this we find, as I have endeavoured to show, that the land-ice came down from the north to a certain well-defined line in New Jersey and Pennsylvania, and that after it melted back the country was submerged beneath a great expanse of water that covered the whole of the lower ground and reached far up the flanks of the hills, and that over this icebergs floated from the north, and dropped, as they melted, large stones brought from far distant ranges. This expanse of water was not limited to the area that the land-ice had covered, but extended far to the south of it into Virginia. After the land-ice retired, or whilst it was retiring, and before the country was submerged to such a depth as to permit the flotation of icebergs from the north, the upper pebble beds containing the stone implements were formed. Dr. Abbott has not only obtained his implements from beds that are clearly seen to have been spread out before the large blocks were scattered over the surface, but in one instance took one from the gravel below one of the large stones. From Mr. Wallace's description his discoveries appear to have been made in gravels of the same age.

West of the Appalachians the evidence all points to the same conclusion. We have in the Northern States, first, glaciated rock-surfaces and patches of till that witness the reign of land-ice; then we have on its retirement a land-surface, with remains of vegetation (peat and forest beds) and of extinct mammals. Along with the latter at some places, at the same horizon in others, have been found the bones and implements of man, as I have described at the commencement of this paper. The next stage is marked by widespread beds of gravel or rolled drift, that indicate the rising of the water. The gravel is covered with brown clay containing great far-transported boulders, witnessing the submergence of nearly the whole country beneath the flood. This brown clay covers the land everywhere in the States of Illinois, Iowa, Kansas, and Nebraska, and I have traced it myself up to the flanks of the Rocky Mountains. It marks as surely the culmination of the great flood as the beds that follow it, the loess, mark its subsidence; when the waters that had before covered the hills began to be confined to the valleys of the great rivers. From this time the mammoth, the megalonyx, the megatherium, the mylodon, the horse (until it was re-introduced from Europe), the gigantic beaver, and the lion were no more seen alive in North America, for their remains are not found in

beds of later age. To the same horizon belong all the instances I have given of the earliest appearance of man in North America, and to it almost certainly must be ascribed the discoveries of Dr. Abbott and Mr. Wallace on the eastern sea-board. The extinct mammals and the earliest appearance of man in North America are therefore prediluvial, as I have urged is the case in Europe: indeed a most striking parallel may be drawn between the series of events that happened in the Glacial period in the eastern and the western continent.

We have first in Europe a great extension of land ice, that from Scandinavia reaching to the south of the Baltic, and that of the Alps to the Jura and down the valley of the Rhone as far as Lyons. We have then the retreat of the ice; and palæolithic man, the mammoth, and the rhinoceros occupying part at least of the area the ice had covered. Then we have a great outspread of gravels and clays, the latter in Northern Europe, with far-transported boulders, reaching up to 1700 feet above the present level of the sea.

I have endeavoured to explain this series of events by the theory that whilst the ice was accumulating on the mountains of Scandinavia and Central Europe, it was also being piled up at the northern end of the Atlantic, and in greater abundance there because of greater precipitation. When it there reached a sufficient height to intercept the moisture in the air-currents travelling northward it would advance down the bed of the Atlantic, partly by flowing as a glacier, but principally because the precipitation was on the southern slope and increased as the ice-ridge progressed southward. Whilst this ridge of ice was moving down the bed of the Atlantic, that from Scandinavia and the Central Alps had culminated, and began to shrink back, for the area of greatest precipitation was now on the Maritime Alps, the Pyrenees, the Cantabrian Range, and the mountains of Asturias, and the accumulation of ice there intercepted the moisture that had before supplied the glaciers of Northern and Central Europe. This I consider was the time of the principal distribution of the mammoth and the woolly rhinoceros, an earlier stage being marked by the presence of *Elephas antiquus* and *Rhinoceros etruscus*. The great accumulations of ice in the northern and southern hemisphere had before this abstracted so much water from the ocean that the level of the latter had been greatly lowered, the rivers cut deeper channels than they now occupy, the bed of the German Ocean was left dry, and many another tract

that is now covered with a shallow sea then formed wide pasture-grounds for the great pachyderms and their associates. Palæolithic man likely lived on higher and drier land, and found a plentiful subsistence amongst the deer and the wild horses and oxen that appear to have abounded.

Probably this state of things was of long duration, but at last there came a catastrophe; possibly the greatest that has befallen the human race, yet of immense benefit in its ultimate results. The ridge of ice in the Atlantic had been slowly advancing, and through time it coalesced with that from the Cantabrian Range, whilst at the same time the gap between the Pyrenees and the Maritime Alps was also closed with ice. I suppose that the communication of the Black Sea with the Mediterranean had not then been effected, and that the ice of the Pacific blocked up the outlet of the waters to Behring's Straits. An immense basin was thus formed, the drainage of which to the sea was intercepted. The consequence would be that the low lands would be soon submerged. The pent-up waters ultimately reached a height of about 1700 feet above the sea, as evidenced by the great outspread of gravels at Munich, Bern, and Geneva; but whether this extreme height belonged to the first or second rise I do not yet know. To this great flood I ascribe the formation of the lower boulder clays and diluvium, and the destruction of the great mammals that were caught on the low plains and have left there their bones in great abundance. The first great European lake was apparently not of long duration, but was suddenly and tumultuously lowered by the breaking away of the ice-dam; probably, I now think, between the Pyrenees and the Maritime Alps. The rushing flood or debacle swept off from the flanks of the hills much of the detritus that covered them, and mingled all together in the great sheets of gravel that are now spread over much of the low country. Thus were formed, I think, the middle sands and gravels (including the Thames and other valley gravels), in which have been caught up or which cover the bones of the pre-diluvial mammals or the stone implements of pre-diluvial man. As no land surface has yet been detected between the middle sands and gravels and the upper boulder clay, it is probable that the break in the rim of the lake basin was soon filled with ice again, and the great lake re-formed. Over it floated icebergs from the north, carrying great boulders from the mountains of Scandinavia and scattering them over the German plain and as far as the flanks of the Carpathians. At this time was formed the upper boulder clay and diluvium

of Europe. The second lake was gradually lowered by the cutting through of the Bosphorus or the Dardanelles, and the various stages of its subsidence are marked in all the great valleys of Northern and Central Europe. In England the upper boulder clay and the upper brick clays of the Thames and other river valleys were at this time deposited. Flint implements appear to have been found in clays of this age, but they do not indicate, I think, that palæolithic man existed, but that pre-diluvial man had left his nearly indestructible stone-work on the hill-sides, higher than the violence of the debacle reached to, and that shore-ice in the second-lake period sometimes carried these away and dropped them in the clay that was then forming. I noticed, in Dr. John Evans' noble collection of stone implements, with surprise, a fact with which he had been long familiar—the sharp, unworn edges of the implements from the brick clays, and also of a few that have been found on the surface at heights of over 300 feet above the sea. These implements have also a whitened bleached appearance, which may be due to long exposure on the surface before being imbedded in the brick clays.

It is now more than two years since I laid this theory before the Geological Society of London,* and no flaw has yet been pointed out in it, whilst in a series of papers published in this Journal I have shown that many other difficult problems in glacial geology besides those to the solution of which I first applied it find in it a simple explanation. I believe it is the only theory that explains the transport of northern boulders across the plains of Germany and Russia; and at the same time accounts for the absence of marine remains testifying that the sea had not occupied the area during the flotation of the blocks; and the absence of glaciated rock-surfaces showing that the Scandinavian land-ice had not extended so far. It is also the only theory of our day that deals with the difficult question of the origin of a great debacle of which De la Beche, Murchison, Sedgewick, and Prestwich have shown us there is so much evidence. The principal feature in the theory is that the advance of the ice of the Glacial period was mostly down the ocean depressions, partly because ice will gravitate towards the lowest levels, and especially because the precipitation of moisture is in our hemisphere much greater at the northern ends of the seas than in similar latitudes inland on the continents.

* "Drift of Devon and Cornwall." Read November 3rd, 1875. Published in abstract only, Quart. Journ. Geol. Soc., February, 1876.

If the northern end of the Atlantic was so occupied with ice as this theory requires, the effects ought to be similar on the west coast of Europe and the east coast of America, which on this view form the left and right banks of the same great valley. I restrict my argument for the present, on the American side, to the country lying east of the Appalachians, but I hope at some future time to show that a similar explanation of the glacial phenomena west of that range is not improbable: this I cannot do now, as the preliminary steps of the discussion would occupy a greater length than the whole of this paper.

Owing to the influence of the Gulf Stream the ice occupying the bed of the Atlantic would probably extend much farther on the American side than on the European. Flowing down there—much influenced by the shape of the ocean bed, still more by the areas of greatest precipitation as affected by the advance of the ice itself, and not necessarily, nor even probably, thickest next the coast line and south of Cape Cod mostly distant from it—the ice, I think, reached so far at least as the 37th parallel of latitude. I suppose that the mass of ice had been increasing as it advanced southward, in consequence of the enormously greater precipitation not having yet been counterbalanced by the also increased waste from liquefaction, and that it flowed in upon the American coast somewhere south of Chesapeake Bay, and blocked up the eastern drainage as far as that point. Thus I think was produced the submergence of all the lower parts of the country. To what height the flood reached I have not information to guide me, but the water must have been deep to permit the tranquil deposition of the brown clays that cover much of the country, and the flotation of icebergs from the north, bearing the great rocks that were thus distributed over the land. I have found no evidence in North America of any great debacle, and the waters do not appear ever to have been suddenly and tumultuously discharged. In consequence, there has not been there the same mixing together of remains of different ages as occurred with us when the middle sands and gravels were spread out, and the relation of the beds containing the relics of pre-diluvial man and the pre-diluvial mammals to the other glacial deposits is more clearly defined. The more gradual and interrupted subsidence of the water is, however, marked by a series of terraces in the valleys. Excepting for this, the parallel between the series of events that occurred in the Glacial period, in Western Europe and North-eastern America, is complete. There is the same evidence of the advance

of the land-ice, of the rivers running in deeper channels, of the formation of forest and peat beds in tracts now below the level of the sea, of the recession of the land-ice, of the interruption of the drainage of the country, and the formation of a continental ice-dammed lake over which floated icebergs. The same evidence, too, that palæolithic man and the extinct mammals were pre-diluvial, and were destroyed or driven out of the country by the rising of the great flood.

That American geologists will follow up the evidences of pre-dilvuial man in the western hemisphere we may be sure, and we may confidently expect that as great advances will be made by them in our knowledge of the relation he bore to the Glacial period as they are making in every other department of geology, and in fact in every branch of science.

It is a matter for congratulation that this question should be in the hands of such a skilled and enthusiastic archæologist as Dr. Abbott, and of such able and cautious geologists as Prof. Cook and Prof. Smock. I feel confident that we shall not have to wait long for confirmation of the position of the implements below the iceberg drift, and for more definite information than we now possess of the height above the sea to which the erratic blocks extend, and the distances they have travelled from the north or north-west. Nor need we despair of evidence soon being found that man was present in the country at the time of the greatest extension of the land-ice; the witness of which, so far, is the solitary scratched chipped pebble from the moraine at Butzville, the fabrication of which by man is doubted by some that have seen it.

I cannot conclude this brief view of the broad features of the glaciation of North-eastern America and the relation of palæolithic man to it, as seen from my standpoint, without again making an appeal for a more thorough examination of the records in our own country. It is susceptible of proof in East Anglia whether or not palæolithic man lived there in the Glacial period. Within a stone's throw at Hoxne lie all the glacial beds—the till, the lower boulder clay, the middle sands and gravels, and the upper boulder clay. There also are the gravels and clays in which Mr. Frere, nearly eighty years ago, found flint implements and bones of extinct mammals; and yet to this day we have not settled the relation that these bear to the glacial beds. Eighteen months ago, in the pages of this Journal, I gave my reasons for believing that the post-glacial age of these

deposits, as assumed by most of our geologists up to that time, had not been proved; and I urged that we ought not to allow the matter to remain doubtful when it could be cleared up by sinking a few shafts in different parts of the ground. No action has been taken by our learned societies to whom I appealed, but now discoveries in other places have caused many to doubt the post-glacial age of some of the deposits containing implements, and they may be more inclined to listen to my appeal.

At Hoxne the expenditure of £200 would probably, and of £500 certainly, I think, show the relations of the deposits there to each other, and clear up the question of the glacial or post-glacial age of the beds containing the relics of palæolithic man and the great pachyderms. Large sums, and with results exceeding our anticipations, have been spent on the exploration of the cavern deposits, and we have ascertained definitely from them that man and the great extinct mammals lived at the same time. We should now take another step, and determine the exact position that the same fauna holds in the geological series; and this can be done at Hoxne. We send out scientific expeditions to the ends of the world, and rightly so I think, and yet here is one of the grandest problems that can interest mankind lying at our doors, and lying neglected. Granted that I may be mistaken, and that Prof. Prestwich—whose geological opinion is properly of much greater weight than mine—may be right; is it not worth while to set the question at rest, and not consume our time in fruitless discussions and barren congresses? My glacial theory is the outcome of many years of study of the phenomena with which it deals, and I know that it has been fashioned with sincerity; but it is not so dear to me that I should hesitate to put my own shoulder to topple over the edifice I have reared if I could find reason to believe that it was not founded on truth. If the explorations that I urge, ought to be undertaken at Hoxne, be carrried out, and prove that the implement-bearing beds are post-glacial, I shall at least have the satisfaction of thinking that not only has my own geological vision been cleared, but that Mr. Prestwich—whose writings for more than twenty years have been my study and delight—has been proved to be right. But trivial and paltry are these personal considerations compared with the issues that are undetermined, and which it is our duty and privilege to clear up, when we have at Hoxne such an opportunity of doing so as is not known to exist anywhere else in Europe.

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